A CPW-fed Rectangular Patch Antenna for WLAN/WiMAX Applications

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***Abstract*— This paper presents a CPW fed Rectangular shaped patch antenna for the frequency 3.42GHz which falls in WiMAX and 5.25GHz for WLAN applications. The measured -10dB impedance bandwidth is about 650MHz (2.98GHz-3.63GHz) for WiMAX and 833MHz (4.95GHz-5.78GHz) for WLAN applications. The effect of slot width, rectangular patch height, and substrate dielectric constant have been evaluated. The results of antenna are simulated by using Zeeland's MOM based IE3D tool. Two dimensional radiation patterns with elevation and azimuth angles, VSWR<2, Return loss of -24dB and -18dB for WiMAX and WLAN applications, antenna efficiency about 90%, gain above 3.5dB are obtained. The compact aperture area of the antenna is 46.2 X 41.66 mm2.**

***Keywords*—Coplanar Waveguide, Patch Antenna, Return Loss**

I Introduction

With the recent wide and rapid development of wireless communications there is a great demand in the design of low-profile, and multiband antennas for mobile terminals [1, 2]. Many antennas, such as the monopole and CPW-fed antennas with dual-band characteristics for wireless applications have been reported [3–6]. There are many bands for WLAN antennas which are studied and published so far. The assigned bands according to IEEE 802.11 b/a/g are 2.4GHz (2.4–2.484 GHz) and 5.2/5.8 GHz (5.15–5.35 GHz/5.725–5.825 GHz). The bands assigned for WiMAX (Worldwide Interoperability Microwave Access) based on IEEE 802.16 are 2.5/3.5/5.5 GHz (2500–2690/3400–3690/5250–5850 MHz) [7-10].

Recently, due to its many attractive features such as wide bandwidth, low cross polarization, radiation loss, less dispersion, uni planar nature, no soldering point, and easy integration with active devices or monolithic microwave integrated circuits (MMICs), the coplanar waveguide (CPW)-fed antenna has been used as an alternative to conventional antennas for different wireless communication systems [11].

In this paper, a novel and simple antenna design has been carried out. A Rectangular shaped patch antenna fed by a CPW transmission line in a single-layer substrate is studied. With this CPW-fed scheme, the manufacture cost of the antenna can be reduced as low as possible. Details of the investigations based on simulations of the proposed antenna for wireless applications are described. First, a brief description of proposed antenna which includes antenna design and geometrical layout is presented in section II. The design methodology of IE3D is illustrated in section III and finally the simulation results of return loss, radiation patterns, antenna gain, efficiency, smith chart are given in section IV. The results are simulated using commercial IE3D simulator [12].

II Proposed Antenna Structure and Design

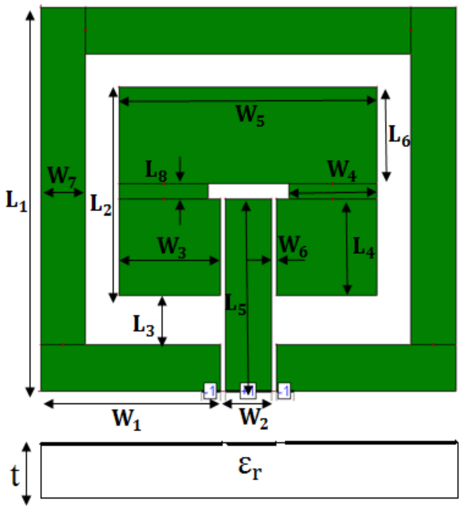

Figure 1. Layout of the proposed Antenna

The geometrical configuration of the proposed CPW-fed patch antenna is shown in Fig.1.The designed antenna is etched on a single layer of RT/Duroid 5880 PTFE glass fibre dielectric substrate whose dielectric constant is εr= 2.2 which is 46.2 X 41.66mm2 in dimension. The antenna is symmetrical with respect to the longitudinal direction, whose main structure is a Rectangular-shaped patch with Co-planar waveguide (CPW) feed line.The geometrical parameters are adjusted carefully and finally the antenna dimensions are obtained to be L1= 41.66mm, L2 = 22.6mm, L3 = 5.3mm, L4 = 10.5mm = L6, L5 = 20.8mm, L8 = 1.6mm, W1 = 20mm, W2 = 5.2mm, W3 = 11.24mm,

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W4 = 9.84mm, W5 = 28.68mm, W6 = 0.5mm, W7 = 5mm. The substrate thickness t=2mm.

III Design Methodology

In order to achieve the required results a commercial CAD tool-IE3D is used. IE3D is based on MoM's boundary element method (BEM). In Moment's method, first a circuit is divided into small subsections. One sub section is taken at a time and calculate the electric field generated everywhere by the current at one section. Place current on all subsections simultaneously and adjust those currents so that total tangential Electric field goes to Zero. Once the Current distribution is obtained, the S parameters follow immediately. BEM creates a mesh like structure over the modeled surface. These meshes are further modeled as matrices which are solved numerically. This is done using "Green's Functions". Green's Functions consist of source and field patches which form the matrix. Green's Functions are integrated over either or both source and field patch if the model is uniform throughout. This is called "Galerkin's Method". IE3D breaks down the structure to be modeled into numerous meshes whose co-ordinates are modeled as a matrix. It calculates the analytical integral over all these meshes by filling the matrix elements for every single frequency.

Technically, a Green's function, G (x, s) , of a linear operator L acting on distributions over a manifold M , at a point s , is any solution of

$$LG(x, s) = \delta(x-s) \quad (1)$$

Where δ is the Dirac delta function. This technique can be used to solve differential equation of the form:

$$Lu(x) = f(x) \quad (2)$$

Suppose the function v (t) is known over the domain of t, specific values of x may be derived from representative expressions, such as equation given below

x= 0t1vtdt (3)

For example, if v (t) = k, x = kt_1. A special case arises when the function v (t) is unknown and values of x are known at only discrete values of t. This type of problem is generally referred to as an integral equation problem where the task is to determine the function. The fundamental concept behind the MoM employs orthogonal expansions and linear algebra to reduce the integral equation problems to a system of simultaneous linear equations. The following procedure shows how to find current expansion coefficient using MoM. We define the unknown current distribution in the electromagnetic field asIzz'. The current distribution is expressed as

n=1NCnGn(z)=Ezz (4)

Where

Gnz=1j4πωε-l/2l/2Fn(z')∂2∂z2+k2e-jkRRdz'(5)

Cn= current's expansion coefficient

Fn(z') = basis function

After applying the boundary conditions, we get a set of integral equations defined by

ZmnIn=Vm (6)

Where

Zmn=-l2l2HmzGnzdz (7)

In=Cn (8)

Vm=-l2l2HmzEzzdz (9)

This circuit, like set of simultaneous equations will lead to the value of Cn.

[In]=Zmn-1Vm (10)

IV Numerical Results and Discussions

To investigate the performance of the proposed antenna configurations in terms of achieving the required results a commercially available moment method based CAD tool- IE3D, was used for required numerical analysis and obtaining the proper geometrical parameters in Fig.1.

Return Loss

The simulated return loss coefficients are shown in Fig. 2. It can be noted that for frequency range 2.98GHz to 3.63GHz a bandwidth of 650 MHz for a -10 dB return loss is observed at 3.43 GHz operating frequency. The return loss at this resonant frequency is obtained as -23.57dB and for frequency range 4.95GHz to 5.78GHz the -10dB bandwidth of 833MHz is observed at 5.27GHz resonant frequency with a return loss of -17.5dB. The return loss curve is obtained more accurately by taking 20 cells per wavelength.

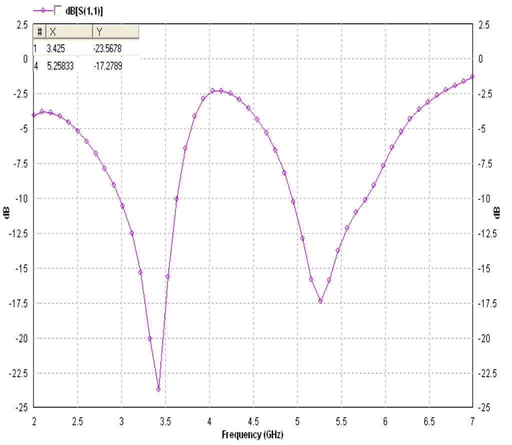

Figure 2: Return loss of the antenna

Radiation Pattern with Elevation and Azimuth angles

The far-field radiation patterns at the operating frequency for the constructed prototype of the proposed antenna are also examined. Figs. 3–6 depict,

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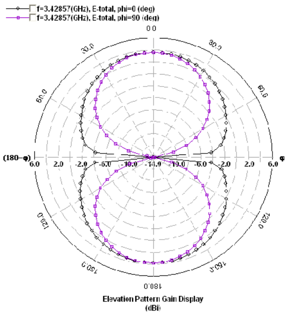
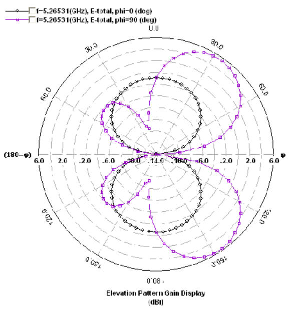
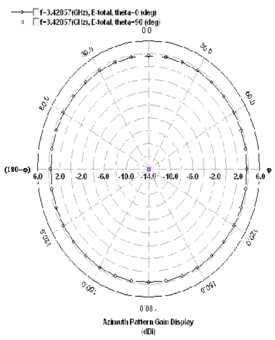
respectively, the measured radiation patterns including Eθ and Eφ polarization patterns in the azimuth cut (*x–y* plane) and the elevation cuts (*y–z* plane and *x–z* plane) for the antenna at the frequencies 3.43GHz and 5.27GHz respectively.

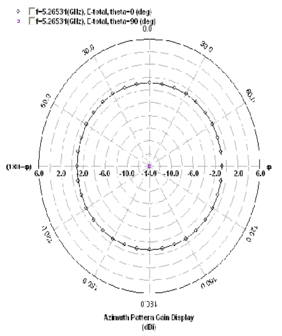




2D Elevation Pattern

Figure 3: At 3.43GHz Figure 4: At 5.27GHz





2D Azimuth Pattern

Figure 4: At 3.43GHz Figure 5: At 5.27GHz.

Antenna Gain and Efficiency

The measured antenna gain and efficiency against frequency for the proposed antenna across the operating band is shown in Fig 7 and Fig 8. It is observed that a gain of about 3.7dBi at 3.43GHz and 5.6dBi at 5.23GHz and efficiency of about 92% at 3.43GHz and 88% at 5.23GHz is obtained.

Voltage Standing Wave Ratio

It is clear from Fig.9. that the simulated voltage standing wave ratio (VSWR) of the proposed antenna is less than 2 for entire frequency bands of 2.98GHz to 3.63GHz and 4.95GHz to 5.78GHz which is desired. The VSWR values at first and second resonant frequencies are observed to be 1.14 and 1.32 respectively which are closer to ideal value which is 1.

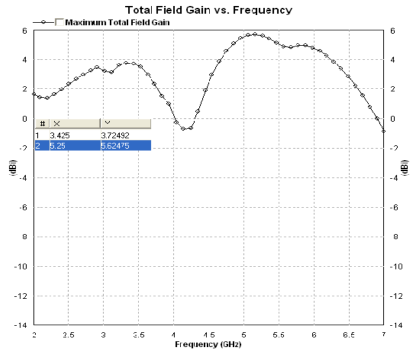


Figure 7. Gain of the proposed Antenna

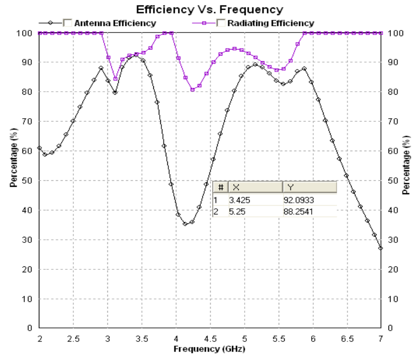


Figure 8. Efficiency of the proposed Antenna

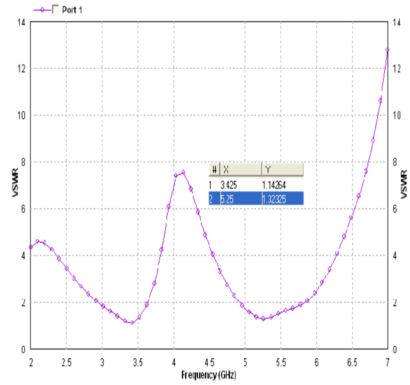


Figure 9. VSWR Curve

Smith Chart

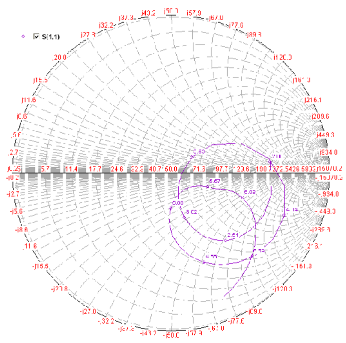


Figure 10. Smith Chart.

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The Fig 10. shows the obtained Smith chart for the antenna. It is clear from the figure that at resonance almost proper impedance matching occurs.

Comparisions of Return Loss

The effect of slot width, dielectric constant and length L4 are evaluated by varying the slot width of CPW feed whose width is W2 , length L4 and dielectric constant of the substrate and the obtained return losses are compared. The compared resonant frequency and S11 values are tabulated in Table I Table II and Table III respectively and corresponding curves are shown in Figures 11-13.

TABLE I.
EFFECT OF LENGTH L_4 ON S_{11} AND RESONANT FREQUENCY F_R

L_4 (in mm)	f_r (in GHz)	S_{11}(in dB) at f_r
10.0	3.34 5.26	-18.56 -15.78
10.5	3.23 5.23	-23.57 -17.50
11.0	3.33 5.15	-28.04 -19.27

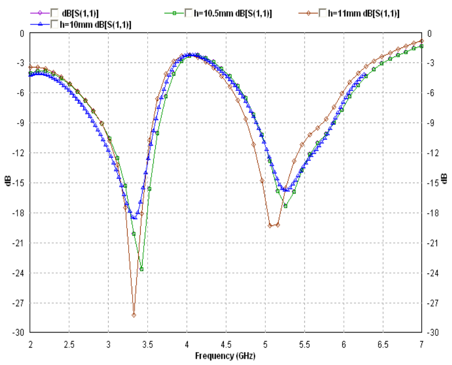

Figure 11. Measured return loss for the proposed antenna with various lengths L4. Other parameters are the same as in Fig. 1.

TABLE II
Effect of Dielectric constant on S11and Resonant Frequency fr

Dielectric constant εr	fr (in GHz)	S11(in dB) at fr
1.5	3.63 5.47	-19.07 -17.25
2.2	3.23 5.23	-23.57 -17.50
3.38	3.02 4.67	-25.24 -24.36
4.4	2.82 4.45	-15.75 -21.28

After few repeated simulations using IE3D, it is found that for L4= 10.5mm, εr= 2.2 and W2= 5.2mm the results are more accurate and resonant frequencies fall in WiMAX and WLAN applications. Moreover it is observed that by increasing the dielectric constant moves the resonant frequency to the left side of graph (decreases) and by increasing the slot width moves the resonant frequency to the right side of graph (increases).

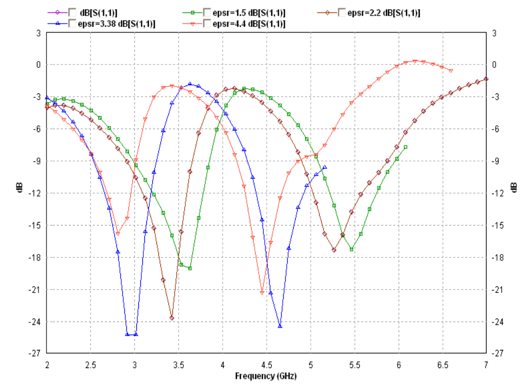

Figure 12. Measured return loss for the proposed antenna with various dielectric constants. Other parameters are the same as in Fig. 1.

TABLE III
Effect of Slot Width W2 on S11and ResonantFrequency fr

Slot Width W2 (in mm)	fr (in GHz)	S11(in dB) at fr
2.0	3.13 4.66	-25.51 -14.89
3.0	3.23 4.84	-34.39 -17.54
4.0	3.23 4.96	-25.23 -20.18
4.6	3.33 5.06	-28.05 -19.62
5.2	3.23 5.23	-23.57 -17.50
5.7	3.43 5.25	-20.41 -13.85

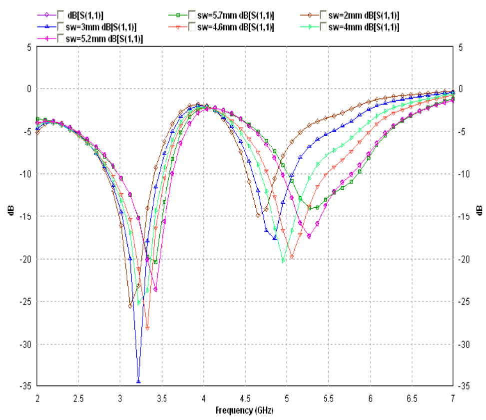

Figure 13. Measured return loss for the proposed antenna with various
slot widthsW2. Other parameters are the same as in Fig. 1.

IV CONCLUSION

In this paper, a CPW fed Rectangular-shaped patch antenna is proposed which does not require external matching circuit. The dimension of the antenna is 46.2 X 41.66mm2. By changing slot width, dielectric constant and length L4 the desired resonant frequency band is achieved. The desired antenna gain, efficiency,

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radiation pattern and VSWR (<2) are obtained. The results are found suitable for WiMAX and WLAN wireless applications.

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